FRDA REPORT 013

NON-TARGET IMPACTS OF THE HERBICIDE GLYPHOSATE
A compendium of references & abstracts

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RATIONALE AND BACKGROUND

The original concept of a compendium of references and abstracts outlining the "non-target impacts of the herbicide glyphosate" arose from the apparent incomplete and scattered sources of information on this subject. A common complaint from both lay and professional people is: "What research has been done on non-target impacts of glyphosate and how do we access this information?" In fact, from the computerized literature search which was conducted to identify studies of non-target impacts of glyphosate, the information in this compendium was extracted from over 1800 references covering non-target impacts, toxicology, and some material on efficacy. Thus, there is a considerable literature base for glyphosate and this compendium evolved as a means of providing, in as complete a manner as possible, a collection of titles and abstracts of articles reporting on the non-target impacts of this herbicide.

As compiler of this document, I have conducted research on the non-target effects of glyphosate over the past ten years. This work has focussed primarily on small mammal populations in forestry and agriculture, as well as food preference and habitat selection by black-tailed deer. Additional work was conducted on fish, daphnids, and diatoms (algae) as part of a major field study. To date, with co-workers, there are nine publications outlining our work on the non-target impacts of glyphosate. Much of my earlier work on mammals is summarized in the chapter "Effects of Glyphosate on Selected Species of Wildlife" from the book "The Herbicide Glyphosate" published in 1985.

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ORIGIN AND USE OF COMPENDIUM

This compendium is designed as an Information Report to provide an objective assessment of the effects of glyphosate on non-target species. The majority of references (scientific journals and proceedings of symposia) have been extracted from a computerized literature search of the following sources.

AGRICOLA (Agriculture 1970-1987)
CHEMICAL ABSTRACTS (American Chemical Society 1973-1987)
AQUAREF (Canadian Water Resources References 1970-1986)
ASFA (Aquatic Sciences and Fisheries Abstracts 1978-1987)
BIOSIS (Biological Abstracts 1969-1987)
CAB (Commonwealth Agriculture Bureau Abstracts 1972-1987)
NTIS (National (U.S.) Technical Information Service 1964-1987)

This search has been directed at a world-wide level and reflects all uses of glyphosate in agriculture, forestry, and industrial rights-of-way. The balance of the references are from manuscripts which were only recently (1987) or not yet published.

Titles and abstracts have been reproduced exactly as they appeared in the original article or as abstracted by the source system. In the case of journal articles without a formal abstract, a summary of the study has been abstracted by the compiler and this is clearly indicated by an asterisk (*).

The compendium is composed of six sections: Mammals, Birds, Fish, Aquatic Invertebrates and Algae, Terrestrial Invertebrates, and Microflora. All titles and abstracts of pertinent references with author(s) and publication outlet are listed alphabetically in each section. References without abstracts are given at the end of each section and represent those publications which could not be obtained by the compiler. References from outside North America are identified by country, wherever appropriate, to assist the reader. References which report on species representing more than one section (e.g. fish and aquatic invertebrates) will appear in each section.

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I. MAMMALS

1. Anthony, A.G. and M.L. Morrison. 1985. Influence of glyphosate herbicide on small mammal populations in western Oregon. Northwest Science 59: 159-168.

The effect of glyphosate application on vegetation and small mammal populations in the Coast Range of western Oregon was investigated. Diversity, abundance, and biomass of small mammal populations increased one year post spray on glyphosate-treated sites as compared to control sites. These changes were ephemeral and above parameters were similar to pre-spray values two years after glyphosate application. The changes in diversity, abundance, and biomass were primarily a result of the increase in numbers of Microtus oregoni following an increase in grass and forb cover on treated grids one year post-spray. The temporary effects of glyphosate treatment on vegetation had no detrimental effects on small mammal populations.

2. Balfour, P. The Effects of Forest Herbicides on B.C. Ungulates and Grizzly Bear Forage Species. B.C. Ministry of Environment and Parks, Wildlife Branch, Victoria, B.C. (Submitted).

(*)Seventy-one percent of the herbicide used in British Columbia forests in 1985 was glyphosate. This percentage is projected to be 78% in 1986. Therefore, glyphosate impacts on wildlife are of primary concern. Approximately 400 out of 1300 entries analyzed were glyphosate trials. Glyphosate is a broad spectrum, relatively non-selective herbicide. Indeed most of the species studied, with the exception of evergreen species, showed instances of severe damage. However, the degree and timing of severe results were varied. Being foliar active, the degree of damage is related to the amount of chemical absorbed and subsequently translocated in the plant. This is a function of method of application, plant characteristics and environmental conditions. The cut-surface applications were severely damaging in nearly all cases.

During the data analysis, conflicting results with regard to season of application were found. It is often assumed that early foliar glyphosate applications will be most damaging as this is the period of most active translocation. Alternatively, when the leaves are at maximum growth there is more surface and increased absorption capabilities. The data analyzed in this study range over every possible permutation of these two theories. However, there is suggestion of some forage species showing particular trends, for instance mallow ninebark was undamaged by early treatments but severely damaged by fall treatments. Further research directed at particular seasonal/phenological sensitivities is warranted for glyphosate. Plant species may also respond on an individual basis to their general health or other

factors unrelated to their species physiology. Plant vigor may also determine ability to absorb and translocate chemicals.

3. Braathe, P. 1978. Damage by elk browsing must be taken seriously. Will our forests contain less pine in future? Norsk Skogbruk 24: 12-13. (Norway)

Although the introduction of even-aged forestry, with consequent large regeneration areas, is probably not the only cause of the population explosion of elks (Alces alces) in recent years, such areas do provide rich browse for elks which are also the only browsers of young pine (Pinus sylvestris). In trials in which insufficient regeneration of Picea abies was supplemented by pine, elk damage was so severe that this method had to be abandoned. Pine is also heavily attacked in natural mixed stands (pine and spruce) and in pure stands. In mixed broadleaf and conifer regeneration elk browse particularly heavily on aspen (Populus tremula) and maple (Acer spp.). It is suggested that by judicious cleaning of regeneration areas with glyphosate the food supply for elk might be greatly reduced thereby reducing the present intolerably high population density.

4. Campbell, D.L., J. Evans, G.D. Lindsey, and W.E. Dusenberry. 1981. Acceptance by black-tailed deer of foliage treated with herbicides. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station; Portland, OR: USDI, Fish and Wildlife Service, Forest-Animal Damage Control Research Project. Olympia, WA. Res. Pap. PNW-290. 31 p.

To test their acceptance of foliage treated with herbicides, captive black-tailed deer were exposed to Douglas-fir seedlings and salal treated with standard formulations of 2,4,5-T, 2,4-D, atrazine, dalapon, fosamine, and glyphosate herbicides. Carriers were diesel oil and water. Tests were made from November 1977 through February 1978. Deer readily browsed 2,4,5-T treatments and most formulations of 2,4-D in oil compared with oil alone, but showed rejection of some phytotoxic glyphosate treatments. Consumption of herbicide-treated foliage did not cause noticeable health problems in test animals.

5. D'Anieri, P., M.L. McCormack, Jr., D.M. Leslie, Jr., and S.M. Zedaker. 1986. The small mammal community in a glyphosate conifer release treatment in Maine. Proceedings, 40th Annual Meeting of the Northeastern Weed Science Society. Pp. 205-209.

Small mammals were trapped in a 1-year-old glyphosate release treatment, a current glyphosate treatment and an unsprayed control in 4-to 5-year-old spruce/fir clearcut in Maine

in 1984. Glyphosate did not affect the total number of small mammals trapped, but decreased the abundance of Clethrionomys gapperi. This was thought due to the creation of a more open habitat by glyphosate. The other main spp. trapped were Peromyscus maniculatus, Sorex cinereus and Microsorex hoyi.

6. Evans, D.D. and M.J. Batty. 1986. Effects of high dietary concentrations of glyphosate (Roundup) on a species of bird, marsupial and rodent indigenous to Australia. Environmental Toxicology and Chemistry 5: 399-401. (Australia)

Refer to Birds section (page 11).

7. Haugen, R. and E. Lunde. 1981. Spraying with glyphosate. I. The effect on vegetation. II. The effect on damage by small rodents. Norsk Skogbruk 27: 13-15. (Norway)

Results of helicopter spraying in August on plots laid out in weed-infested 7-year-old spruce plantations on various site types in Nord Trondelag, Norway are discussed. Most of the species particularly harmful to spruce were highly susceptible; a few could be classed as tolerant, including Vaccinium vitis-idaea. Grass was controlled up to 100% and herbs, including V. myrtillus, up to 70%, suggesting that treatment might deprive field mice of much of their food and (in snow-free periods) cover. Such control of vegetation developing after fellings, might reduce infestation of clear fellings by small rodents. However, it was also found that spraying increased the sugar content of spruce bark wood and needles (in the case of bark up to 41%), which might make trees more palatable to rodents.

8. Jones, R. and J.M. Forbes. 1984. A note on effects of glyphosate and quinine on the palatability of hay for sheep. Animal Production 38: 301-303. (United Kingdom)

Sheep were used in a Latin-square exeriment to investigate the effect of preharvest treatment of pasture with glyphosate (Roundup), a translocated herbicide, on the palatability of hay. Four hays were used: control (C), Roundup (R), quinine (Q) (100 mg/kg), and Roundup with quinine (QR). During each week one of the following choices was given to each animal: (a) C/C; (b) C/R; (c) R/R; (d) Q/C; (e) Q/R; and (f) C/QR. There were no significant effects of treatment on the proportion chosen or on total daily intake, mean meal size, or rate of eating. Thus, neither preharvest treatment with Roundup nor postharvest treatment with quinine affected
the palatability of hay.

9. Kennedy, E.R. and P.A. Jordan. 1985. Glyphosate and 2,4-D: The impact of two herbicides on moose browse in forest plantations. Alces 21: 149-160.

Conifer plantations in northeastern Minnesota are important browse areas for moose. The U.S. Forest Service has recently shifted to glyphosate (Roundup) as the predominant herbicide for controlling hardwood shrub competition in plantations. Glyphosate is a systemic toxin that kills the entire plant so little resprouting occurs. Previously, the preferred herbicide was 2,4-D, which allows vigorous sprouting. We sampled available browse in glyphosate and 2,4-D treated stands. Three years after spraying, the glyphosate stands averaged only half the available browse as the 2,4-D stands. While sensitivity to 2,4-D differs markedly among woody plant species, glyphosate kills woody species more uniformly. Grass and raspberries are not controlled one year after spraying because glyphosate has no residual effects. We could not measure longterm effects in this study because glyphosate was not used in this region before 1981. This report covers only the first half of a 2-year study.

10. May, T.A., D.E. May and M.L. McCormack, Jr. 1982. Plant response to herbicides in clearcut conifer strips. Proceedings of the 36th Annual Meeting of the Northeastern Weed Science Society, 36: 205-208.

Plant species composition and abundance were measured in regenerating (4-5 years) clearcut strips in Maine spruce-fir forests prior to, one year after, and three years after application of varying rates of glyphosate, glyphosate in combination with 2,4-D, and triclopyr. Changes in plant species indices were used to categorize plant response to the herbicides used. The implications of these changes to wildlife use of herbicide-modified clearcut strips are discussed.

11. Morrison, M.L. and E.C. Meslow. 1983. Impacts of forest herbicides on wildlife: Toxicity and habitat alteration. Transactions of the 48th North American Wildlife Conference pp. 175-185.

Our review indicates that the response of wildlife to herbicide-induced habitat change is extremely varied. Variations in response by wildlife are understandable given that plants respond in a species-specific manner to the chemical applied, the rate and time of application, and various environmental constraints. What generalizations can be drawn then? First, we have seen that certain animals respond to habitat alteration by increasing their use of undamaged vegetation. Other species, however, are seemingly unable to compensate for habitat loss and thus decline in density. Other species respond to habitat change

by increasing in density. This shift in concentration of density is due, quite simply, to changes in the amount of preferred habitat available to each species following treatment. An increase in density by certain species following treatment is not necessarily desired, for this change has been artificially induced by a management practice. Increasing deer browse through herbicide application, for example, would also cause a decreased habitat availability for other species. The general response of wildlife to herbicide application can thus be predicted if data are available on the range of habitats occupied by a species and their density in these habitats. Changes anticipated in animal communities can be alleviated, in part, by careful planning of treatment. What is generally deemed desirable is retention of the natural variety of vegetation types so that managed lands can supply a diversity of vegetation and wildlife through time.

12. **Newton, M. K.M. Howard, B.R. Kelpsas, R. Danhaus, C.M. Lottman and S. Dubelman. 1984. Fate of glyphosate in an Oregon USA forest ecosystem. Journal of Agricultural and Food Chemistry 32: 1144-1151.**

Glyphosate herbicide residues and metabolites were evaluated in forest brush field ecosystems in the Oregon coast range aerially treated with 3.3 kg/ha glyphosate. Deposits were recorded at various canopy depths to determine interception and residues in foliage, litter, soil, streamwater, sediments and wildlife for the following 55 days. The half-life of glyphosate ranged from 10.4 to 26.6 days in foliage and litter and twice as long in soil. The treated stream peaked at 0.27 mg/l and decreased rapidly; concentrations were higher in sediment than in water and persisted longer. Coho salmon fingerlings did not accumulate detectable amounts. Exposure of mammalian herbivores, carnivores and omnivores and retention of herbicide seemed to vary with food preference; however, all species had visceral and body contents at or below observed levels in ground cover and litter, indicating that glyphosate will not accumulate in higher trophic levels. (Aminomethyl)phosphonic acid was found at low concentrations but degraded rapidly. N-Nitrosoglyphosate was nondetectable.

13. **Newton, M., E.C. Cole, R.A. Lautenschlager, D.E. White and M.L. McCormack. 1988. Browse availability after conifer release in Spruce-Fir forests of Maine. Journal of Wildlife Management (Submitted).**

Even-aged forest management in northern spruce-fir types may lead to high production of high-quality browse species from year 3 to years 9 or more after clearcutting. Rapid growth of hardwoods and dense growth of conifers reduce foliage and twig volumes below 2.5 m to a low level by year 16. Application of

glyphosate, triclopyr or phenoxy herbicides in August of year 7 reduced tall hardwood cover and increased available browse below 2.5 m by factors of 4-8. Nearly all species present before treatment remained present for at least 9 years after treatment. Available browse after treatment includes a higher ratio of sun-grown foliage and twigs, than controls. Spacing of conifers by planting or pre-commercial thinning should prolong the period of high quality browse conditions to well beyond the 20th year. Treatments causing the greatest control of the tallest hardwood species provided the most accessible browse and also the highest proportion of sun-grown material. When using glyphosate, the short period of reduced forage availability after treatment suggests splitting large units and treating in phases separated by about two years.

14. Ritchie, D.C., A.S. Harestad, and R. Archibald. 1987. Glyphosate treatment and deer mice in clearcut and forest. Northwest Science 61: 199-202.

Prior to planting conifers, herbicides are commonly used to reduce competition from deciduous trees and shrubs. Herbicides are usually not toxic to wildlife but do affect their habitats. We examined deer mice (Peromyscus maniculatus) to assess the impact of herbicides on small mammals. Deer mice from adjacent untreated and glyphosate-treated clearcuts had similar body sizes and numbers of placental scars and foeti. In untreated clearcut, deer mice were more abundant than in treated clearcut, but were less abundant than in surrounding old growth forest. Glyphosate altered vegetation and reduced density of deer mice in young seral stages. Habitat changes induced by glyphosate likely modified abundance and quality of food and cover for small mammals.

15. Sullivan, T.P. 1988a. Influence of a herbicide application on small mammal populations in coastal coniferous forest: I. Population density and resiliency. Ecology (Submitted).

This study was designed to assess the responses of small mammal populations to herbicide-induced habitat alteration in a 7-year-old Douglas fir (Pseudotsuga menziesii) plantation near Maple Ridge, British Columbia, Canada. These populations included the deer mouse (Peromyscus maniculatus), Oregon vole (Microtus oregoni), Townsend chipmunk (Eutamias townsendii), shrews (Sorex spp.), and several less common species. Population density and colonization rate or resiliency were measured on 1-ha non-removal and pulse-removal live-trap grids in control and treatment plantation habitats from April 1981 to September 1983; non-removal grids only were sampled from April to October 1985. Glyphosate herbicide was aerially applied to the treatment area in June 1982. There was little difference in abundance of deer

mice, Oregon voles, and shrews between control and treatment study areas. Chipmunk populations appeared to decline temporarily on the treatment grids relative to controls. The resiliency or colonization rate of voles was not affected by habitat change. However, resiliency of the deer mouse population on the treatment area was lower than that recorded on the control. Deer mouse and Oregon vole populations were each at comparable densities on control and treatment areas in the second and fourth years after herbicide treatment. These small mammal species should be able to persist in areas of coastal coniferous forest which are treated with glyphosate herbicide for conifer release.

16. Sullivan, T.P. 1988b. Influence of a herbicide application on small mammal populations in coastal coniferous forest: II. Reproduction, growth, and survival. Ecology (Submitted).

This study investigated the direct effects of a forest application of herbicide on reproduction, growth and survival in deer mouse (Peromyscus maniculatus), Oregon vole (Microtus oregoni), and to a limited degree, Townsend chipmunk (Eutamias townsendii) populations. Non-removal and pulse-removal live-trap grids (1-ha) in control and treatment plantation habitats near Maple Ridge, British Columbia, Canada, sampled populations from April 1981 to September 1983; non-removal grids only were monitored from April to October 1985. Glyphosate herbicide was aerially applied to the treatment area in June 1982. Reproductive performance of deer mice and Oregon voles, in terms of length of breeding periods, proportion of breeding animals, and number of successful pregnancies, was unaffected by glyphosate. In fact, there were significantly more breeding deer mice in the treatment than control population in 1983, and this may have contributed to poor early juvenile survival of mice by limiting recruitment on the treatment area. Survival of animals, in general, was similar in control and treatment populations of all three species. However, female voles did survive significantly better in the treatment than control population in the post-spray summer of 1982 and winter of 1982-83. Lack of consistent differences in body weights, and somewhat better growth rates of deer mice and voles in treatment than control populations, during post-spray periods, indicated that glyphosate had no effect on metabolic or general physiological processes in the development of young animals. Physiological changes in individual animals, from exposure to or ingestion of glyphosate, and manifestation of these effects in demographic attributes at the population level were not apparent in this study.

17. Sullivan, T.P. and E.J. Hogue. 1987. Influence of Orchard floor management on vole and pocket gopher populations and damage in apple orchards. Journal of the American Society for Horticultural Science 112: 972-977.

Removal of all vegetation with herbicides over the total orchard floor or only in tree rows significantly reduced montane vole (Microtus montanus Peale), meadow vole (M. pennsylvanicus Ord), and northern pocket gopher (Thomomys talpoides Richardson) populations and damage. Herbicide treatments in four test orchards were carried out during May, July, and Sept. 1983 to 1985. Average overwinter abundance of voles was reduced 53% to 99% on treatment areas. Several vole populations went to extinction in the third year of herbicide treatment. Incidence of tree damage was 40.6% and 9.6% with feeding intensities of 17.2 cm^2 and 0.4 cm^2 of bark and tissues removed per tree on control and treatment blocks, respectively, during a peak year in abundance of voles. Pocket gopher populations and damage were significantly lower in treatment than control blocks. Deer mouse (Peromyscus maniculatus Wagner) and yellow pine chipmunk (Eutamias amoenus J.A. Allen) populations generally increased on treated areas. Use of herbicides to control orchard floor vegetation is an effective means of rodent damage control.

18. Sullivan, T.P. and D.S. Sullivan. 1979. The effects of glyphosate herbicide on food preference and consumption in black-tailed deer. Canadian Journal of Zoology 57: 1406-1412.

The use of herbicides is an important part of forestry managment practices in the Pacific Northwest because the regeneration of coastal forests is hampered by many species of deciduous shrubs and weeds. The herbicide glyphosate is used to control these undesirable species. Some effects of glyphosate on black-tailed deer have been investigated by analyzing food preference and consumption under simulated field conditions. Deer given a choice of control or glyphosate-treated alder and alfalfa browse showed no preference or ate more of the treated foliage. The ingestion of treated browse did not affect the consumption of laboratory chow by the deer. These results indicate that spraying with the herbicide glyphosate should not prevent deer from feeding on foliage in the affected area.

19. Sullivan, T.P. and D.S. Sullivan. 1981. Responses of a deer mouse population to a forest herbicide application: reproduction, growth, and survival. Canadian Journal of Zoology 59: 1148-1154.

This study was designed to monitor some of the demographic responses of a deer mouse population to a forest application of

Roundup® herbicide. Populations of Peromyscus maniculatus were livetrapped from July 1978 to November 1980 on a control area and in a herbicide-treated 20-year-old Douglas-fir plantation at Maple Ridge, British Columbia. The herbicide had no apparent adverse effects on reproduction, growth, or survival of deer mice 1 year after treatment. Inconsistencies in growth rates and juvenile survival between control and experimental deer mice in 1980 could be due to the herbicide or demographic factors. Field dose applications of this herbicide should not have a direct effect on the dynamics of deer mouse populations.

20. Sullivan, T.P. and D.S. Sullivan. 1982. Responses of small-mammal populations to a forest herbicide application in a 20-year-old conifer plantation. Journal of Applied Ecology 19: 95-106.

The responses of small-mammal populations in a forest application of Roundup® herbicide have been investigated at the University of British Columbia Research Forest, Maple Ridge, B.C., Canada. These populations included the deer mouse, Oregon vole, Townsend chipmunk, and shrews. Treatment of a 20-year-old Douglas fir plantation did not have any negative effects on the distribution and abundance of small-mammal populations during the first year after this habitat alteration. Movements of deer mice were monitored by drift lines. There was not an influx of new animals from the surrounding regions onto the treated area nor was there a significant movement of marked animals away from the sprayed area. Future changes in composition of the small-mammal community may occur in association with successional stages advancing from the herbicide-induced habitat alteration.

21. Timmerman, H.R., J.G. McNicol and C.S. Krishka. 1986. Impact of glyphosate on wildlife habitat: A three year study. Ministry of Natural Resources, Wildlife and Forest Resources Branch, Government of Ontario.

This study was designed to establish the impact of aerial application of glyphosate for conifer release (in the boreal forest of northern Ontario) by studying the changes in vegetative composition and density, and its effect on the winter utilization by moose and snowshoe hare and fall utilization by small mammals, over a three year study period. Treated and adjacent untreated areas are being studied and compared to determine differences, if any, due to herbicide treatment. The study methodology is designed to assess changes over a three year period in the vegetative community on areas treated with glyphosate through comparison with similar untreated areas. Changes in the vegetative community may affect the utilization of treated sites by herbivores (moose and small mammals) and thus carnivores (terrestrial furbearers). Periodic assessment would be benficial

after the initial three-year study to observe long term changes, i.e. 5, 10 and 15 years.

22. Wahlgren, J.R. 1979. The effects of the herbicide Roundup^{R} on reproduction in mice. B.S. Agr. Thesis, Dept. of Animal Science, University of British Columbia, Vancouver, B.C.

The herbicide Roundup^{R} has the potential for increased use in the control of competitive shrub and tree species in forest plantations. This report examines the effect of Roundup^{R} on reproductive performance in mammals which may inhabit these forest ecotypes. Laboratory mice are used as test animals. For the variable chosen to represent the physiological processes of reproduction, no differences were found using F-tests and Chi-squared analyses at the five per cent probability level. The experiment was run over a period of two litters from the same parents.

II. BIRDS

1. Batt, B.D.J., J.A. Black and W.F. Cowan. 1980. The effects of glyphosate herbicide on chicken egg hatchability. Canadian Journal Zoology 58: 1940-1942.

Hatchability and time to hatch of chicken eggs were found to be unaffected by application of glyphosate herbicide at three different concentrations and at four different embryo ages. We concluded that the use of the chemical as a weed control agent in zero tillage farming should not negatively affect the hatchability of the eggs of upland nesting birds.

2. Evans, D.D. and M.J. Batty. 1986. Effects of high dietary concentrations of glyphosate (Roundup) on a species of bird, marsupial and rodent indigenous to Australia. Environmental Toxicology and Chemistry 5: 399-401. (Australia)

Five zebra finches, Phoephila guttata, allowed unrestricted access to seed containing 5000 .mu.g glyphosate/g all died in 3-7 days, but they may well have died from starvation since their food consumption was drastically reduced. Six finches survived after ingesting seed containing 2500 .mu.g glyphosate/g for 5 days. The marsupial Sminthopsis macroura, and 2 species of hopping mouse, Notomys alexis and N. mitchelli survived on a diet in which the concentration of glyphosate was increased from 625 .mu.g/g to 5000 .mu.g/g by doubling the concentration of glyphosate in the food every few days during a 23-day period. The only toxic effect observed in the mammals was a marked body weight loss in the treated N. alexis. Thus, glyphosate for the 4 species is probably nontoxic to slightly toxic.

3. Hoffman, D.J. and P.H. Albers. 1984. Evaluation of potential embryotoxicity and teratogenicity of 42 herbicides, insecticides, and petroleum contaminants to mallard eggs. Archives of Environmental Contamination and Toxicology 13: 15-27.

The embryotoxicity of 42 environmental contaminants applied externally to mallard (Anas platyrhynchos) eggs including crude and refined petroleum, and complete formulations of herbicides and insecticides, are reported. Many of the petroleum pollutants were embryotoxic and moderately teratogenic and had LD50s of 0.3-5 .mu.L/egg (approximately 6-90 .mu.g/g egg). The most toxic was a commercial oil used for control of road dust followed by South Louisiana crude oil, Kuwait crude, no. 2 fuel oil, bunker C fuel oil, and industrial and automotive waste oil. Prudhoe Bay crude, unused crankcase oil, aviation kerosene, and aliphatic hydrocarbon mixtures were less toxic (LD50s of 18 to > 75 .mu.L)

and less teratogenic. The median lethal concentrations (LC50s) of herbicides and insecticides in aqueous emulsion were measured by egg immersion: the most toxic were paraquat (1) and trifluralin (LC50s of approximately 1.5 lbs/acre; 1.7 kg/ha). Propanil, bromoxynil with MCPA, Methyl diclotop, Prometon, endrin, sulprofos, and parathion were toxic (LC50s of 7-40 lbs/acre; 7.8-44.8 kg/ha), whereas 2,4-D, glyphosate, atrazine, carbaryl, dalapon, dicamba, methomyl, and phosmet were only slightly toxic or not toxic (LC50s of 178 to > 500 lbs/acre; 199-560 kg/ha). Pesticides in nontoxic oil vehicle applied by microliter pipet were up to 18 times more toxic than when applied in water vehicle, which was probably due to better penetration of the pesticide past the eggshell and its membranes. Teratogenic effects and impaired embryonic growth are reported and results discussed in terms of potential hazard at field levels of application. A discussion is provided on the effects of pollutants on the eggs of other species of birds under laboratory and field conditions.

4. Morrison M.L. and E.C. Meslow. 1984. Effects of the herbicide glyphosate on bird community structure western Oregon USA. Forest Science 30: 95-106.

Vegetative changes induced by the herbicide glyphosate and the resultant habitat use of birds nesting on 2 clearcuts in western Oregon were studied. About 23% of total plant cover was initially damaged by aerial application of glyphosate. Most measures of vegetation on the treated site decreased relative to the untreated site 1 year after glyphosate application. By 2 years post spray, vegetation on the treated site had recovered to near prespray status. No difference in density of the bird community was evident between treated and untreated sites during all years of study, although individual species densities were modified. Several bird species decreased their use of shrub cover and increased their use of deciduous trees 1 year after treatment. By 2 years postspray, many species returned to prespray use of most measured habitat components. Results indicated that application of glyphosate can modify the density and habitat use of birds.

TITLES

5. Spidso, T.K. and N. Hovik. 1984. A pilot experiment of the effect of glyphosate on the growth and survival of Capercaillie tetrao-urogallus chicks. Symposium on Tetraonid Energetics, Tvarminne, Finland. (42): 41. (Finland)

III. FISH

1. **Folmar, L.C., H.O. Sanders and A.M. Julin. 1979. Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. Archives of Environmental Toxicology and Contamination 8: 269-278.**

Studies were initiated to determine the acute toxicity of technical grade glyphosate (MON0573), the isopropylamine salt of glyphosate (MON0139), the formulated herbicide Roundup^{R} (MON02139), and the Roundup^{R} surfactant (MON0818) to four aquatic invertebrates and four fishes: daphnids (Daphnia magna), scuds (Gammarus pseudolimnaeus), midge larvae (Chironomous plumosus), mayfly nymphs (Ephemerella walkeri), Rainbow trout (Salmo gairdneri), fathead minnows (Pimephales promelas), channel catfish (Ictalurus punctatus), and bluegills (Lepomis macrochirus). Acute toxicities for Roundup ranged from 2.3 mg/L (96-h LC50, fathead minnow) to 43 mg/l (48-h EC50, mature scuds). Toxicities of the surfactant were similar to those of the Roundup formulation. Technical glyphosate was considerably less toxic than Roundup or the surfactant; for midge larvae, the 48-h EC50 was 55 mg/L and for rainbow trout, the 96-h LC50 was 140 mg/L. Roundup was more toxic to rainbow trout and bluegills at the higher test temperatures, and at pH 7.5 than at pH 6.5. Toxicity did not increase at pH 8.5 or 9.5. Eyed eggs were the least sensitive life stage, but toxicity increased markedly as the fish entered the sac fry and early swim-up stages. No changes in fecundity or gonadosomatic index were observed in adult rainbow trout treated with the isopropylamine salt or Roundup up to 2.0 mg/L. The aging of Roundup test solutions for seven days did not reduce toxicity to midge larvae, rainbow trout or bluegills. In avoidance studies, rainbow trout did not avoid concentrations of the isopropylamine salt up to 10.0 mg/L; mayfly nymphs avoided 10.0 mg/L of Roundup, but not 1.0 mg/L. In a simulated field application, midge larvae avoided 2.0 mg/L of Roundup. Application of Roundup, at recommended rates, along ditchbank areas of irrigation canals should not adversely affect resident populations of fish or invertebrates. However, spring applications in lentic situations, where dissolved oxygen levels are low or temperatures are elevated, could be hazardous to young-of-the-year-fishes.

2. **Folmar, L.C. 1976. Overt avoidance reaction of rainbow trout fry to 9 herbicides. Bulletin of Environmental Contamination and Toxicology 15: 509-514.**

(*) The results of these studies suggest that rainbow trout would not be killed by, and would not avoid, relatively low concentrations of dalapon, 2,4-D (DMA), glyphosate, Aquathol K, diquat, or TCA. However, trout present in acrolein-treated water

probably would not avoid a lethal exposure. Trout strongly avoided low concentrations of copper sulfate and 0.1 mg/l xylene; although these chemicals are non-toxic at the levels tested, their presence in the water may influence the selection of habitat by fish.

3. **Hildebrand, L.D., D.S. Sullivan and T.P. Sullivan. 1982. Experimental studies of Rainbow Trout populations exposed to field applications of Roundup^{R} herbicide. Archives of Environmental Contamination and Toxicology 11: 93-98.**

This paper reports the effects of Roundup^{R} herbicide (MON 02139) on rainbow trout viability and behavior in several field experiments at the University of British Columbia Research Forest. Laboratory and field 96-hr LC50 values were similar: 54.8 and 52.0 mg/L. Avoidance-preference data indicated that fish would avoid lethal levels of Roundup. Operational application of Roundup at the recommended field dose of (2.2 kg a.e./ha), as well as 10X and 100X field dose resulted in no mortality to rainbow trout in field streams. Results indicate that operational spraying with this herbicide for weed control should not be detrimental to rainbow trout populations. Improper use or accidental spills of Roundup could be avoided by rainbow trout and should not be lethal if diluted in a moderately-flowing stream.

4. **Holtby, L.B. and S.J. Baillie. 1987. Effects of the herbicide "Roundup" on Coho Salmon fingerling in an over-sprayed side-channel of Carnation Creek, British Columbia. Proceedings of the Carnation Creek Herbicide Workshop, Nanaimo, B.C. December 8-10, 1987. (In press).**

The responses of coho salmon fingerlings are described, following the over-spraying of a permanent side-channel of Carnation Creek with the herbicide "Roundup". Qualitative observations of caged coho fingerlings at exposed sites in the over-sprayed side-channel indicated some stress 2 hours after application and subsequently some mortality (2.6%) of those fish was observed. Caged fish at other sites showed no similar signs of stress and no mortality immediately after application. We observed no unusual mortality of the approximately 300 coho fingerlings estimated to be resident in the side-channel at the time of the herbicide application. In comparison with unaffected sites, trapping efficiencies in the side-channel did decline after the application and remained depressed for at least 4 months, suggesting that coho fingerlings were less active in the over-sprayed side-channel. In comparison with 1-3 years of pre-spray data, no changes in overwinter mortality, growth rates, or the probabilities of entering and leaving the side-channel were observed for two years following application.

5. Mitchell, D.G., P.M. Chapman and T.J. Long. 1987. Seawater challenge testing of coho salmon smolts following Roundup® herbicide exposure. Archives of Environmental Contamination and Toxicology (In press).

Concentrations of Roundup® herbicide up to ten times those encountered in the environment immediately after aerial application (2.78 mg/L) did not affect 24 hour seawater survival, nor plasma sodium concentration, hematocrit or growth in 10 day exposures with yearling coho salmon (Oncorhynchus kisutch). Similarly, no abnormal responses were noted when a 10 day freshwater recovery period was provided between the herbicide and seawater exposures. These results indicate that the application of Roundup® at the manufacturer recommended use-rates for forestry management will not adversely affect the ability of coho salmon smolts to adapt to seawater and osmoregulate normally.

6. Mitchell, D.G., P.M. Chapman and T.J. Long. 1987. Acute toxicity of the glyphosate herbicide Roundup® (Vision®) to Rainbow Trout, Chinook and Coho Salmon. Bulletin of Environmental Contamination and Toxicology (In press).

(*) Roundup®, also known by the tradename Vision®, is a herbicide manufactured by Monsanto Company which may enter aquatic environments during the course of normal usage. This paper summarizes the results of aquatic toxicity testing of this herbicide using three different fish species, different-sized fish, and differences in dilution water (type/source, pH, hardness, and conductivity). There was no significant difference ($p < 0.05$) in the toxicity of Roundup/Vision to 0.37 g rainbow trout, 4.6 g chinook salmon and 11.8 g coho salmon. Acute toxicity values ranged from 7.4 mg/L to 12 mg/L in terms of the IPA salt of glyphosate, with 95% confidence limits ranging from 5.7 - 18 mg/L. Varying dilution water type (dechlorinated, dechlorinated and reconstituted, and natural lake water), pH (range 6.1-7.7), hardness (4.5-85 mg/L as $CaCO_3$) and conductivity (12-132 umhos/cm) did not significantly affect Roundup/Vision toxicity to 0.37 g rainbow trout. The results of this study indicate that, according to a toxicity classification scheme currently in use, Roundup/Vision herbicide would be considered to be slightly toxic to trout and salmon species. Thus, no hazard to aquatic environments would be expected during the course of normal usage.

7. Newton, M., K.M. Howard, B.R. Kelpsas, R. Danhaus, C.M. Lottman and S. Dubelman. 1984. Fate of glyphosate in an Oregon forest ecosystem. Journal of Agricultural and Food Chemistry 32: 1144-1151.

Glyphosate herbicide residues and metabolites were evaluated in forest brush field ecosystems in the Oregon Coast Range

aerially treated with 3.3 kg/ha glyphosate. Deposits were recorded at various canopy depths to determine interception and residues in foliage, litter, soil, streamwater, sediments, and wildlife for the following 55 days. The half-life of glyphosate ranged from 10.4 to 26.6 days in foliage and litter and twice as long in soil. The treated stream peaked at 0.27 mg/L and decreased rapidly; concentrations were higher in sediment than in water and persisted longer. Coho salmon fingerlings did not accumulate detectable amounts. Exposure of mammalian herbivores, carnivores, and omnivores and retention of herbicide seemed to vary with food preference; however, all species had visceral and body contents at or below observed levels in ground cover and litter, indicating that glyphosate will not accumulate in higher trophic levels. (Aminomethyl)phosphonic acid was found at low concentrations but degraded rapidly. N-Nitrosoglyphosate was nondetectable.

8. **Servizi, J.A., R.W. Gordon and D.W. Martens. 1987. Acute Toxicity of Garlon 4 and Roundup herbicides to Salmon, Daphnia, and Trout. Bulletin of Environmental Contamination and Toxicology 39: 15-22.**

(*) This report summarizes the acute lethality of Garlon 4, Roundup and a surfactant (MON0818) contained in the formulation of the latter to sockeye salmon (Oncorhynchus nerka), Daphnia pulex, rainbow trout (Salmo gairdneri) and coho salmon (Oncorhynchus kisutch). The mean 96-hour LC50 of Garlon 4 for sockeye was 1.3 mg/L at 4.5°C and pH 7.9, while the 96-hour EC50 for Daphnia was 1.2 mg/L at 21°C. The 96-hour LC50's for coho and rainbow trout were 2.2 mg/L at 15°C and pH 6.2. Sockeye fingerlings and fry were equally susceptible to Roundup; the 96-hour LC50 averaged 27.7 mg/L when tested at pH 7.7 to 8.0. For Daphnia the 96-h EC50 was 25.5 mg/L. The average 96-hour LC50 for rainbow trout was 26.8 mg/L; and for a single test of coho the 96-hour LC50 was 42 mg/L. The sum of toxic units for glyphosate and MON0818 ranged from 1.39 to 1.92 for the sockeye, Daphnia, rainbow and coho tested in moderately or weakly buffered waters.

9. **Singh, S.P. and N.K. Yadav. 1978. Toxicity of some herbicides to major carp fingerlings. Indian Journal of Ecology 5: 141-147. (India)**

As a consequence of herbicide treatment in or near fish habitats, fish are likely to be killed due to direct effects of the herbicides and indirectly due to asphyxiation following the disappearance of vegetation. Ten herbicides were, therefore, evaluated for their acute toxicity to major carp (Cirrhina mrigala) fingerlings at concentrations of 1 to 100 ppm. Copper sulphate proved to be most toxic, caused 40 percent fish

mortailty at 1 ppm, and 2,4-D amine was least toxic, causing no mortality even at 100 ppm concentration. Other herbicides in the order of decreasing toxicity to fish were paraquat > glyphosate > terbutryne > diuron > simazine > dalapon > diquat > MSMA. In the presence of coontail (Ceratophyllum demersum), a submerged aquatic plant, the recommended field rates of simazine, paraquat and diuron were found to be toxic to fish exposed for 24 days.

10. Tooby, T.E., J. Lucey and B. Stott. 1980. The tolerance of grass carp, Ctenopharyngodon idella Val., to aquatic herbicides. Journal of Fish Biology 16: 591-597.

Because grass carp may feed selectively on water plants, additional conventional methods may be necessary for effective control of aquatic vegetation. For economic reasons aquatic herbicides are most likely to be used in conjunction with grass carp within an integrated aquatic weed control programme. The acutely lethal toxicities of ten herbicides (asulam, cyanatryn, 2,4-D-amine, dalapon, dichlobenil, diquat, diuron, glyphosate, paraquat, and terbutryne) to grass carp were measured. A preliminary evaluation of the risk to these fish showed that, when used at the recommended rate, the maximum herbicide concentration likely to be found in water should cause little harm to the fish, although attention should be given to the possible inhibition of feeding.

11. Tooby, T.E. 1985. Fate and biological consequences of glyphosate in the aquatic environment. In: The Herbicide Glyphosate. Edited by E. Grossbard and D. Atkinson. Butterworths, London. Pages 206-217.

(*) Glyphosate, when used as recommended by the manufacturer, is unlikely to enter watercourses through run-off or leaching following terrestrial application. Clearly, significant residues could enter water when Roundup is used as an aquatic herbicide. In static water, residues decline fairly rapidly due mainly to adsorption onto particulate matter. In some flowing water the conditions could be such that glyphosate could remain in solution or adsorbed onto particulate matter in suspension, for some distance downstream from the point of application. Although the rate of degradation of residues depends on pH, temperature and the presence of microorganisms, most aquatic environments likely to receive Roundup treatment will provide the most ideal conditions for degradation. The field experience seems to support the laboratory predictions that residues will be adsorbed and will eventually break down. Therefore, it is unlikely that glyphosate will affect aquatic organisms at the concentrations found in the environment after use at the recommended rates. It is also unlikely that residues will be accumulated in fish tissues.

12. Wan, M., R. Watts, and D. Moul. 1988. Toxicity to salmonids of the herbicide glyphosate (Roundup) and its surfactant. Department of the Environment. Environmental Protection, Pacific Region. Regional Program Report 86-16. (In press).

In 1984, static fish bioassays were conducted by the Environmental Protection, Service, Pacific Region and Yukon, of Environment Canada to determine the acute toxicity to juvenile salmonids of herbicide Roundup™ and its surfactant MON0818. This study indicated that Roundup™ was only moderately toxic to two species of Pacific salmon. The average 96 hr LC_{50} values for the fish were: Coho salmon (42.3 mg/L), and Rainbow trout (32.4 mg/L). However, the surfactant MON0818 was highly toxic to salmonids, with 96 LC_{50} values of 3.2 and 3.5 mg/L for Rainbow trout and Coho salmon, respectively. The stabilisation time of LC50 values varied with different fish for Roundup™, but appeared to be 96 hours for the surfactant MON0818. Analytical results of selected test water samples indicated that the free acid equivalent of glyphosate in Roundup™ was approximately 30%. Also glyphosate did not degrade to any significant degree during the 96-hour test period. The implications of these results and their potential short term impact on Pacific salmonid species are discussed.

TITLES

13. Sacher, R.M. 1978. Safety of Roundup in aquatic environment, Proceedings of the European Weed Research Society 5th Symposium on Aquatic Weeds, Amsterdam, pp. 315-322.

14. Tooby, T.E. 1981. Predicting the direct toxic effects of aquatic herbicides to non-target organisms, Proceedings of a Symposium on Aquatic Weeds and their Control, Christ Church, Oxford, 7-8 April, pp. 265-274.

IV. AQUATIC INVERTEBRATES AND ALGAE

1. Christy, S.L., E.P. Karlander, and J.V. Parochetti. 1981. Effects of glyphosate on the growth rate of Chlorella. Weed Science 29: 5-7.

Growth rates, in terms of cell doublings per day, were determined for cells of C. sorokiniana inoculated into media containing from 5.91 x 10 sup - sup 6M to 591 x 10 sup-sup 6M glyphosate. Comparisons with a control, which supported 10.4 doublings/day, showed growth only slighly reduced at 5.91 x 10 sup - sup 6M and 11.8 x 10 sup - sup 6M, with averages of 9.7 and 9.5 doubling/day; reduced by more than half at 17.7 x 10 sup - sup 6M with an average of 4.4 doublings/day; and prevented at all higher concentrations. In addition to completely preventing growth at 23.7 x 10 sup - sup 6M and above, glyphosate seemed to cause a deterioration of the inoculum cells. Filtering the media containing 5.91 x 10 sup - sup 6M 11.8 x 10 sup - sup 6M, and 17.7 x 10 sup - sup 6M through kaolinite prior to introduction of the alga reduced the inhibition previously noted at 17.7 x 10 sup - sup 6M and resulted in growth rates from 9.1 to 9.5 doublings/day.

2. Folmar, L.C. 1978. Avoidance chamber responses of mayfly nymphs exposed to eight herbicides. Bulletin of Environmental Contamination and Toxicology 19: 312-318.

In a Y-shaped avoidance maze, mayfly (Ephemerella walkeri) nymphs avoided the highest test concentrations of $CuSO_4$ (0.001-0.1 mg Cu^{+2}/L, diquat (0.01-1 mg/L), and Roundup (0.1-10 mg/L), but did not avoid 2,4-D DMA (2,4-D dimethylamine salt) (1-100 mg/L), acrolein (0.001-0.1 mg/L), dalapon (0.1-10 mg/L), xylene (0.1-10 mg/L), and Aquathol K (0.1-10 mg/L). The nymphs displayed a marked attraction to 1 mg dalapon/L. The sensitivity of mayfly nymphs to these herbicide pollutants is compared with the sensitivity of rainbow trout fry, and the results are discussed with regard to the impact of herbicide pollution on sport fisheries.

3. Forney, D.R. and D.E. Davis. 1981. Effects of low concentrations of herbicides on submersed aquatic plants. Weed Science 29: 677-685.

Laboratory studies were conducted to investigate the possibility that herbicide runoff from treated fields might be adversely affecting submersed aquatic plants in the Chesapeake Bay (USA). In laboratory studies, I1 and I50 values (the concentrations inhibiting growth 1 and 50%, respectively) were calculated for 3 herbicides and several aquatic plants. Exposure

periods were 3-6 weeks, with the 3 week exposure being most common. For atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine), I1 values were usually a few ppb, whereas I50 values varied from approximately 80 ppb for Elodea (Elodea canadensis Michx) to approximately 1040 ppb for Eurasian watermilfoil (Myriophyllum spicatum L.). The toxicity of metribuzin (4-amino-6-tert-butyl-3-(methylthio)-as-triazin -5(4H)-one) was similar to that of atrazine. Glyphosate (N-(phosphonc ethyl) glycine) was essentially non-toxic. Interactions between salinity and atrazine were studied using the brackish water species, Vallisneria (Vallisneria americana Michx.). Increasing salinity did not affect atrazine toxicity. When atrazine was present in both the hydrosoil and water, the concentration in the water determined the toxicity. At concentrations below 1000 ppb, atrazine in the hydrosoil did not adversely affect the plants. These herbicides apparently do not pose any threat to the species tested.

4. **Goldsborough, L.G. and D.J. Brown. 1987. Effects of aerial spraying of forestry herbicides on aquatic ecosystems. Part III. Bioassay of the effect of glyphosate on carbon fixation by intact periphyton communities. Manitoba Environment and Workplace Safety and Health. Water Standards and Studies Report 87-3, 27 p.**

As part of a three-year study examining potential effects of herbicide use in forest management on adjacent aquatic ecosystems, artificial substrata (acrylic rods) were positioned in shallow water within six experimental study ponds near Pine Falls (96° 10'W, 50° 37'N) during late summer. The substrata were permitted to colonize with periphytic algae for a period of 41 to 50 days, after which samples were collected and exposed in the laboratory to concentrations of glyphosate (added as the commercial formulation Roundup) ranging from 0 to 1800 mg/L. Carbon fixation rates during the first four hours after herbicide treatment were measured, and the change in rate relative to untreated controls was used to assess the short-term effects of glyphosate on algal photosynthesis. Effects of glyphosate treatment on carbon fixation were not detected in samples from any pond at concentrations less than about 0.89 mg/L. Carbon fixation occurred at the highest tested concentration. Estimated EC_{50} values for Pine, Hike and Birch Ponds ranged from 35.4 to 69.7 mg/L glyphosate. Based on the estimated glyphosate concentration which could result from a hypothetical application of 2.5 L/ha Roundup to the study ponds (0.06-0.10 mg/L), no immediate effects of herbicide treatment on periphytic algal photosynthesis are predicted.

5. **Hartman, W.A. and D.B. Martin. 1985. Effects of four agricultural pesticides on Daphnia pulex, Lemna minor, and Potamogeton pectinatus. Bulletin of Environmental Contamination and Toxicology 35: 646-651.**

The toxicity of glyphosate, atrazine, alachlor and carbofuran to D. pulex, L. minor and P. pectinatus was studied at 0.1-10.0 mg/L and the effect of suspended sediment on the toxicities of these pesticides was also examined. Carbofuran (10 mg/L) had no toxic effects on L. minor with or without suspended sediment. Atrazine and alachlor were toxic to Lemna, and the presence of suspended sediment was relatively unimportant in reducing or increasing the toxicity. The above chemicals had no effect on sprouting of P. pectinatus.

6. **Hildebrand, L.D., D.S. Sullivan and T.P. Sullivan. 1980. Effects of Roundup herbicide on populations of Daphnia magna in a forest pond. Bulletin of Environmental Contamination and Toxicology 25: 353-357.**

(*) D. magna populations were arranged in pens in 4 stations in an experimental pond to determine the effects of Roundup (glyphosate). Each station was sprayed with one of the following: pond water alone, field dose (2.2 kg/ha), 10 x field dose and 100 x field dose of Roundup. Survival of D. magna populations was not significantly altered between control and experimental treatments at 2, 4 and 8 days. This study, which attempted to simulate aerial application of Roundup herbicide, indicated that there were no detectable effects on D. magna.

7. **Holtby, L.B. and S.J. Baillie. 1987. Effects of the herbicide "Roundup" on periphyton in Carnation Creek, British Columbia. Proceedings of the Carnation Creek Herbicide Workwhop, Nanaimo, B.C. December 8-10, (In press).**

Periphyton standing crops and accumulation rates were monitored at several sites in the main-stem and side-channels of Carnation Creek for 18 months after the herbicide "Roundup" was applied at a rate of 2.2 kg glyphosate/ha to much of the valley floor of the watershed. One side-channel was over-sprayed. There is evidence of direct toxicity of some herbicide component two weeks after the mid-September application. In the year following spraying there was some localized enhancement of production as the periphyton responded to increased levels of phosphorus immediately downstream of the over-sprayed side-channel.

8. Holtby, L.B. and S.J. Baillie. 1987. Litter-fall and detrital decomposition rates in a side-channel of Carnation Creek, British Columbia, over-sprayed with the herbicide "Roundup". Proceedings of the Carnation Creek Herbicide Workshop, Nanaimo, B.C. December 8-10, (In press).

Litter-fall was measured in the riparian zone of a side-channel over-sprayed with the herbicide "Roundup" for 18 months after application. Defoliation of the riparian zone of the side-channel reduced deciduous litter-fall to approximately 6% of the expected total deposition of 300 $mg^{-2}.d^{-1}$. Coniferous litter was a minor component of all treatment and control sites, averaging less than 1% of the total. At the three control sites coniferous litter-fall increased by an average of 296% in the year after spraying compared to the year before, but in the treatment area the increase was only 36%. Litter decomposition rates in water were variable in the three summers during which measurements were made. Decomposition rates were greatest in the over-sprayed side-channel and lowest in the control side-channel. Between-site differences in decomposition rates were probably the result of differences in their macro-invertebrate communities. Most of the between-year variability in decomposition rates was accounted for by differences in stream temperatures. The herbicide had no measurable effects on macro-invertebrate abundance or community composition. Decomposition rates and the activity levels of macro-invertebrates in the over-sprayed side-channel increased in the summers after spraying, probably as a result of increased summer temperatures that resulted from defoliation of the riparian zone.

9. Hutber, G.N., L.J. Rogers and A.J. Smith. 1979. Influence of pesticides on the growth of cyanobacteria. Z. Allg. Mikrobiol. 19: 397-402. (United Kingdom)

Two unicellular and 2 filamentous cyanobacteria (blue-green algae) were exposed under conditions optimal for photoautotrophic growth to 11 pesticides. Low concentrations (0.01-5 ppm) of diuron, atrazine and paraquat inhibited growth. With MCPA, MCPP, 2,4-D, milstem, and ethrel, marked inhibitory effects were achieved only at concentrations above 100 ppm. Growth was inhibited by glyphosate, DDT, and thiram at intermediate concentrations. In some cases, the effective concentration of the pesticide varied considerably with the organism tested.

10. Maule, A. and S.J.L. Wright. 1984. Herbicide effects on the population growth of some green algae and cyanobacteria. Journal of Applied Bacteriology 57: 369-379.(United Kingdom)

Six herbicides were tested for their effects on the population growth of a range of green algae and cyanobacteria by

an easily replicated low-volume liquid culture technique using Repli-dishes. Diuron, propanil and atrazine were most inhibitory, chlorpropham was intermediate and MCPA and glyphosate were least inhibitory. Chlorpropham was more inhibitory to green algae than to cyanobacteria. The effects of chlorpropham and 3-chloroaniline, a metabolite, on populations of the cyanobacterium Anacystis nidulans and the alga Chlamydomonas reinhardti were monitored in larger scale batch cultures. Both compounds reduced the growth rate although in some cases there was partial recovery. 3-Chloroaniline was less inhibitory than the parent herbicide chlorpropham.

11. Prasad, R. 1984. Impact of glyphosate on Macrophytes. Plant Physiology 75: 139.

Glyphosate is currently being employed in forests for preparation of new sites, conifer release and production of nursery stocks. It is very efficacious against many shrubs and hardwood species and may replace 2,4-D and 2,4,5-T in future. Widespread usage in forestry may result in contamination of the aquatic environments; therefore experiments were carried out under laboratory conditions to determine the impact of glyphosate on two aquatic plants (Lemna minor and Salvinia natans). Both these species inhabit the forest ecosystem and, are part of the food-web of wildlife and fish. Using a range of concentration, formulation and pH it was found that, glyphosate is considerably toxic to these aquatic plants (ED_{50}: 5 ppm for L. minor). Preliminary experiments showed that commercial formulations were less potent than the technical grade material. Hydrogen ion concentration (pH) of the culture medium had some influence on phytotoxicity. Generally the higher the pH, the greater the toxicity. Further investigations are underway to determine the metabolic fate in terrestrial and aquatic ecosystems.

12. Scrivener, J.C. and S. Carruthers. 1987. Changes in the invertebrate populations of the main stream and back channels of Carnation Creek, British Columbia, following spraying with herbicide. Proceedings of the Carnation Creek Herbicide Workshop, Nanaimo, B.C. December 8-10, (In press).

Populations of benthic and epibenthic invertebrates were monitored at two sites in the main stream and at sites with bare mud and mud with rooted vegetation substrates in four tributary swamps. Three tributary swamps (750-trib, 1500-trib, 1600-trib) and one site in the main stream could have been influenced by the herbicide "Roundup" (glyphosate) after its aerial application. In the swamps, densities of invertebrates were 3 to 10 times greater on substrates with rooted vegetation than on substrates of bare mud. In the main stream density of fish-food organisms

was negatively correlated with stream flow. After frequent fresheting and herbicide application, densities were 42% lower at the treated versus untreated main-stream site, although the difference was not statistically significant (p=0.12). In the swamps, density of the epibenthos was related to stream flow with a cubic polynomial (r2=0.45). Peak densities were observed during median stream flow, while minimum densities occurred during periods of minimum and maximum stream flows. After the herbicide treatment, 8% lower densities occurred during median flows and 100% lower densities occurred after freshets in the treated versus untreated swamp.

13. Servizi, J.A., R.W. Gordon, and D.W. Martens. 1987. Acute toxicity of Garlon 4 and Roundup herbicides to Salmon, Daphnia, and Trout. Bulletin of Environmental Contamination and Toxicology 39: 15-22.

Refer to Fish Section (page 16).

14. Shindo, N., Y. Yamamoto, M. Ohyama and A. Murakami. 1986. Effect of several herbicides against microalgae. Meiji Daigaku Nogakubu Kenkyu Hokoku 71: 9-18. (Japan)

Growth inhibitor effects of 6 herbicides on microalgae, e.g. Anabaena cylindrica, Chlamydomonas reinhardti, and Cyclotella sp., were investigated. The growth and photosynthesis of the microalgae were inhibited by Me 3,4-dichlorophenylcarbamate, 1,3-dimethyl-1-(5-trifluoromethyl-1,3,4-thiadiazol-2-yl)urea, or oxadiazon at the 10 ppm level, but not by 2,4-D or $NaClO_3$. Glyphosate had little effect on respiration at 30 ppm, but slightly reduced photosynthesis.

15. Sullivan, D.S., T.P. Sullivan and T. Bisalputra. 1981. Effects of Roundup herbicide on diatom populations in the aquatic environment of a coastal forest. Bulletin of Environmental Contamination and Toxicology 26: 91-96.

(*) This paper reports the effects of Roundup^R herbicide (MON 02139) on diatom populations in several field experiments at the University of British Columbia Research Forest, Maple Ridge, B.C., Canada. A 20-year old Douglas fir plantation received an aerial application of Roundup^R herbicide at the recommended rate of 2.2 kg a.i./ha. Sediment samples and slides available for colonization by algae were used to assess the effects of this herbicide on the phytoplankton of a stream and pond. In another stream Roundup^R was manually applied at field, 10x and 100x field doses and colonization slides were used to assess toxicity to phytoplankton. It was concluded that variations in abundance of diatoms observed in the ponds and streams were mainly determined by habitat and seasonal factors rather than the aerial or manual application of herbicide.

16. Tooby, T.E. 1985. Fate and biological consequences of glyphosate in the aquatic environment. In: The Herbicide Glyphosate. Edited by E. Grossbard and D. Atkinson. Butterworths, London. Pages 206-217.

Refer to Fish Section (page 17).

17. U.S.D.I. 1981. Fisheries and Wildlife Research 1980. U.S. Department of the Interior, Fish and Wildlife Service. 201p.

The acute toxicity of three widely used herbicides to fish and invertebrates was determined: atrazine at 24 ppm was not toxic to rainbow trout, bluegills or daphnids; neither was metribuzin at 40 ppm to rainbow trout and daphnids; nor purified 2,4,5-T at 100 ppm to daphnids, scuds or midges. In one experiment in South Dakota to investigate the effects of herbicides on aquatic plants and invertebrates in the northern prairie wetlands and pothole lakes, the presence of 50 ppm suspended sediment reduced the toxicity of glyphosate to daphnids to about one-third. Further studies indicated that 28% of the radioactivity accumulated by daphnids exposed to C^{14}-PCP at 50 ppb was detected as polar, water-soluble metabolites. Dechlorination and methylation were the major pathways of PCP disappearance in hydrosoil interfaces. High vegetative biomass and photosynthetic rates mitigated the toxic effects of PCP, allowing increased survival and fecundity in several fish species.

TITLES

18. Buikema, A.L., E.F. Benfield and B.R. Niederlehner. 1981. Effects of pollution on freshwater invertebrates. Journal of the Water Pollution Control Federation 53: 1007-1015.

19. Hartman, W.A. and D.B. Martin. 1984. Effect of suspended bentonite clay on the acute toxicity of glyphosate to Daphnia-pulex and Lemna-minor. Bulletin of Environmental Contamination and Toxicology 33: 355-361.

20. Nishiuchi, Y. 1978. Toxicity of formulated pesticides to some fresh water organisms. Suisan Zoshoku 25: 148-150.

21. Richardson, J.T., R.E. Frans and R.E. Talbert. 1979. Reactions of Euglena gracilis (Algae) to fluometuron, MSMA, metribuzin, and glyphosate (toxicity). Weed Science 27: 619-624.

V. TERRESTRIAL INVERTEBRATES

1. **Boller, E.F., E. Janser and C. Potter. 1984. Testing of the side-effects of herbicides used in viticulture on the common spider mite Tetranychus urticae and the predacious mite Typhlodromus pyri under laboratory and semi-field conditions. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz 91: 561-568. (Switzerland)**

The side-effects of herbicides used in viticulture on Tetranychus urticae and the predacious Typhlodromus pyri were studied under laboratory and field-pot experiments in Switzerland in 1983. Mortality rates obtained in the laboratory did not reflect the situation in the field. A relatively simple laboratory test was used to measure mortality, repellency and survival rates. Generally, the herbicides that showed the most intensive repellency in the laboratory (Reglone (diquat), Gramoxone (paraquat), Semparol (a mixture of atrazine, MCPP (mecoprop) and 2,4,5-T) and Caragard combi (a mixture of terbuthylazine and terbumeton)) were most likely to cause population increases of Tetranychus urticae in the field. The herbicides most toxic to both mite species in the laboratory were Roundup (glyphosate) and Basta (glufosinate).

2. **Eijsackers, H. 1985. Effects of glyphosate on the soil fauna. In: The Herbicide Glyphosate. Edited by E. Grossbard and D. Atkinson. Butterworths, London. Pages 151-158. (The Netherlands)**

(*) To summarize this review paper, it must be concluded that experiments carried out in the field so far indicate that the side-effects of glyphosate on the soil fauna are small or absent. Nevertheless, there are some results of laboratory experiments which need confirmation. The 100% mortality in the experiments with Amblyseius fallacis, for instance, should be verified under more realistic conditions because of the less drastic effects found with related Acarina such as Gamasida. For the two isopod species Philoscia muscorum and Oniscus asellus, there was a distinct decrease in longevity compared with the control animals (31 and 38%, respectively) with application of recommended amounts of glyphosate (5.96 ml/m^2). However, the first species was not affected by glyphosate if offered by means of litter from sprayed shrubs. Although, in both experiments, changes in litter fragmentation through spraying of glyphosate were observed, it is difficult to evaluate effects of this herbicide on litter breakdown. The 30% increase in birch litter fragmentation occurring over the period of 6 months after spraying is well within the range of normal fluctuations in litter breakdown in Mull and Mor soil profiles with a high and low biological activity, respectively. However, these

differences might also add to the increased litter fragmentation resulting from herbicide application, leading to increased differences in litter breakdown between treated and untreated plots. Moreover, an evaluation of the differences is connected intimately with the total change in vegetation cover caused by the herbicide. Long-term field trials could elucidate this problem. At present, glyphosate doe not seem to be very toxic for the soil fauna, although adverse effects have been observed in studies with a number of representatives of the soil fauna. The limited number of observations, however, does not permit generalizations of these conclusions.

3. Gomez, M.A. and M.A. Sagardoy. 1985. Influence of glyphosate herbicide on the microflora and mesofauna of a sandy soil in a semiarid region. Revista Latinoamericana de Microbiologia 27: 351-358. (Argentina)

The effect of four applications (0, 2, 4 and 8 L/ha) of the herbicide glyphosate (N-phosphonomethyl glycine) on the total numbers of aerobic bacteria, micro-arthropods, mites and spring tails were studied periodically during 96 days in a sandy soil located in the semiarid region of the Buenos Aires province, Argentina. The total numbers of the microflora did not change significantly ($p = 0.05$) neither with time nor with the mentioned treatments. The total numbers of the other groups were unaffected significantly by the herbicide treatments. However, significant variations with time ($p < 0.01$) took place in the microarthropod population. Furthermore, a highly significant ($R = 0.95^{**}$) relationship was obtained between the total numbers of arthropods and mites. Soil humidity was shown to have no effect on the total number of the organisms studied. From the results, it may be concluded that glyphosate herbicide, applied even in amounts double that usually recommended, does not produce harmful effects on the microflora and the mesofauna studied.

4. Hislop, R.G. and R.J. Prokopy. 1981. Integrated management of phytophagous mites in Massachusetts (U.S.A.) apple orchards. 2. Influence of pesticides on the predator Amblyseius fallacis (Acarina: Phytoseiidae) under laboratory and field conditions. Protection Ecology 3: 157-172.

Forty orchard spray materials were evaluated in laboratory and/or field trials for toxicity to different strains of Amblyseius fallacis, the most important predator of the spider mites Panonychus ulmi and Tetranychus urticae in Massachusetts apple orchards. In laboratory trials, materials highly toxic to the Bishop strain were methomyl, carbaryl, phosalone, diazinon, demeton, dimethoate, fenvalerate, permethrin, formetanate hydrochloride, ammonium sulfamate, paraquat, and glyphosate.

Materials of moderate toxicity were phosphamidon, dicofol, karathane, cyhexatin, and daminozide. Materials of low toxicity were malathion, phosmet, azinphosmethyl, methyl parathion, endosulfan, methoxychlor, propargite, fenbutatin-oxide, benomyl, dodine, glyodin, maneb, dikar, thiram, dichlone, captan, ferbam, maneb-zinc, simazine, dalapon, ethephon, NAA and calcium chloride. Benomyl leaf residues interfered with reproductive capability. In field research plot trials, phosalone, permethrin, and benomyl reduced the numerical response of A. fallacis to prey increase, resulting in spider mite build-up. Endosulfan, azinphosmethyl, phosmet, and methyl parathion had little effect on A. fallacis abundance, resulting in predator-prey ratios favorable to biological control of spider mites. In commercial orchards receiving combinations of phosalone, formetanate hydrochloride, ammonium sulfamate, benomyl, and/or glyodin, A. fallacis was unable to respond maximally to increasing spider mite abundance, necessitating repeated acaricide treatments. In commercial orchards receiving none of these materials, but instead treated with azinphosmethyl, phosmet, endosulfan, captan, and/or dodine, spider mites rarely succeeded the economic injury level, owing in large part to the more favorable A. fallacis-spider mite ratios.

5. **Roorda, F.A., G.G.M. Schulten, and A.H. Pieterse. 1978. The susceptibility of Orthogalumna terebrantis Wallwork (Acarina: Galumnidae) to various pesticides. Proceedings of the 5th EWRS International Symposium on Aquatic Weeds, Amsterdam. Pp. 375-381. (The Netherlands)**

Orthogalumna terebrantis, a mite which has potential for integrated control of Eichhornia crassipes, was tested for its direct susceptibility to 2,4-D, glyphosate, diquat and paraquat. Only diquat was markedly toxic to adults. In addition, direct toxicity of certain insecticides was studied. These included insecticides which are used for the control of disease-carrying insects in marshes and of agricultural pests in the near vicinity of water bodies where E. crassipes occurs. Susceptibility of adults and immatures to these compounds varied considerably, diazinon and endosulfan giving the highest mortality.

6. **Saly, A. and P. Ragala. 1984. Free living nematodes bio indicators of the effects of chemicals on the soil fauna. SB Uvtiz (Ustav Vedeckotech Inf Zemed) Ochr Rostl 20: 15-21. (Czechoslovakia)**

Soil nematodes are bioindicators of pesticide and fertilizer effects on edaphon. In the vineyard soil treated with Roundup herbicide, 38 nematode species were identified. The application rate of 12 L/ha stimulated the nematode community numbers; 2.5 times higher rate reduced them on the average to 63.8% of the

control. Nematodes reacted to the herbicide rates and to the sampling terms by changes in population levels, community composition and weight of their biomass and bound energy value.

7. Vythilingam, I. and T.H. Chua. 1983. The effects of herbicides on soil collembola in Oil Palm Estates. Tropical Ecology 23: 165-172. (Malaysia)

The effect of 2 herbicides, Roundup and Paracol on soil Collembola was investigated in an oil palm estate (Malaysia) from July 1977-June 1978. Compared to the control plot, the Collembola population increased slightly ($p = 0.05$) in the plots treated with Roundup at 11 oz/acre; Roundup at 15 oz/acre and Paracol at 2 pt/acre significantly reduced the collembolan population, with Paracol having a significantly greater effect ($p = 0.05$). Other factors like moisture content, presence of cover crops, food supply and predator population may also indirectly affect the Collembolan population.

8. Wright, M.A., D.A. Kendall and B.D. Smith. 1985. Toxicity of paraquat, paraquat + diquat and glyphosate to the cereal aphid Rhopalosiphum padi. in Tests of agrochemicals and cultivars, London. Association of Applied Biologists. Pp. 8-9. (United Kingdom)

Recent experiments suggest that spread of barley yellow dwarf virus (BYDV) by cereal aphid vectors moving from volunteers, grass weeds and grass leys to following cereal crops can be controlled as a side effect of herbicide use. Experiments were done to find if paraquat, paraquat + diquat and glyphosate are toxic to Rhopalosiphum padi which is one of the most important vectors of BYDV between cereals and grasses. Aphids were rapidly killed by paraquat or paraquat + diquat when sprayed either on or off plants, but not by glyphosate. They were also killed by paraquat and paraquat + diquat when placed on plants after sprays had been allowed to dry. R. padi characteristically feeds near the bases of cereal plants and aphids survived for 17 hours when only the tops of the plants received paraquat or paraquat + diquat. Where only the bases of plants had received spray, some aphids moved upwards away from the treated tissue but most died. Paraquat and paraquat + diquat killed aphids on plants when used in concentrations equivalent to 200 g a.i./ha (i.e.) 1/4 of the recommended field dose for herbicide activity. When fed to aphids in sucrose solutions through Parafilm membranes both paraquat and paraquat + diquat killed aphids at concentration equivalents of 100-400 g a.i./ha. At the highest concentration mortality was less because aphids were deterred from feeding. Glyphosate was not toxic when used in this way.

9. **Yokoyama, V.Y. and J. Pritchard. 1984. Effect of pesticides on mortality, fecundity, and egg viability of Geocoris pallens (Hemiptera: Lygaeidae). Journal of Economic Entomology 77: 876-879.**

Sublethal doses of the insecticides carbaryl, methidathion and methomyl, the acarides dicofol and propargite, the herbicide glyphosate, the defoliant DEF (s,s,s-tributyl phosphorotrithioate) and the fungicide sulfur were tested as cotton leaf residues on Geocortis pallens, a major predator in Californian cotton. No pesticide except propargite significantly increased adult mortality 25-192 hours after a 24-hour acute exposure; neither did they have any detrimental effect on female mortality, fecundity or egg viability. This suggests that deleterious long-term effects in predator populations would not occur if insects survived initial treatments. Males were more susceptible to methidathion and methomyl and females were more susceptible to propargite. Females exposed to DEF laid more eggs. Potential beneficial effects of chemicals on predator populations should be considered in the selection of pesticides for pest management programs.

10. **Zaitseva, V.K. 1981. Specific behavioral reactions of forest red ants to glyphosate treatment. Ekol. Zashch. Lesa 6: 71-75. (Soviet Union)**

Broad-leaf tree control exposes the beneficial forest red ant (Formica rufa) to the arboricide glyphosate. Spraying anthills at 2-6 kg I/ha did not affect ant behavior or the expansion of anthills.

TITLES

11. Hoy, J.B., D.L. Dahlsten and P.J. Shea. 1982. The effects of 2,4-D and an alternative material (glyphosate) used for brushfield rehabilitation on soil arthropod community and litter decomposition rate, Final Report USA-UCB, Research Agreement No. PSW-81-0026, 34 p.

12. Leslie, G.W. 1977. The toxicity of some agrochemicals to Pheidol sp. (Hymenoptera: Formicidae) a common ant in natal cane fields. Proceedings of the Annual Congress of South African Sugar Technology Association 51: 21-23.

13. Martin, N.A. 1982. The effects of herbicides used on asparagus on the growth rate of the earthworm Allolobophora caliginosa, Proceedings of the 35th New Zealand Weed and Pest Control Conference, pp. 328-331.

14. Robinson, A.F., C.C. Orr and J.R. Abernathy. 1977. Influence of Nothanquina phyllobia on silverleaf nightshade. Proceedings of the 30th Annual Meeting of the Southern Weed Science Society, p. 142.

VI. MICROFLORA

1. **Bogdanovic, V.V. 1975. Study of the herbicide effects upon some soil microorganisms. Mikrobiologija 12: 121-125. (Yugoslavia)**

Spraying the soil of an apple orchard with 10 kg simazine/ha did not affect the soil microorganisms. Caragard increased the total numbers of microorganisms, and especially those of fungi and actinomycetes. Roundup increased the total microorganisms and aerobic ammonifiers, but inhibited fungi and actinomycetes.

2. **Carlisle, S.M. and J.T. Trevors. 1986. Effect of the herbicide glyphosate on nitrification denitrification and acetylene reduction in soil. Water, Air, and Soil Pollution 29: 189-204.**

The effect of glyphosate on soil respiration and H_2 oxidation in an agricultural soil was investigated. The effects of the pure herbicide and commercial formulation, Roundup^R (Monsanto Company), were compared in soil under both aerobic and anaerobic conditions. Both formulations stimulated O_2 uptake as well as aerobic and anaerobic CO_2 evolution. Roundup caused more stimulation than glyphosate under aerobic incubation conditions; the formulations had an equal effect on anaerobic CO_2 evolution. Hydrogen oxidation was inhibited by both formulations in aerobic and anaerobic soil. Aerobic oxidation was inhibited to the same extent by both formulations; Roundup had a stronger inhibitory effect on anaerobic H_2 oxidation than did glyphosate. No toxicity to any of these activities should be seen at recommended field application rates of the herbicide.

3. **Chan, K. and S.C. Leung. 1986. Effects of paraquat and glyphosate on growth, respiration, and enzyme activity of aquatic bacteria. Bulletin of Environmental Contamination and Toxicology 36: 52-59. (Hong Kong)**

(*) The present paper reports the results of a study on the effects of paraquat and glyphosate on growth, respiration and enzyme activity of aquatic bacteria. Experimental pools A, B and C were located at the Lam Tseun River in Hong Kong. All these pools were gravel pits with surface areas of 25, 23 and 21 m^2, and mean depths of 0.8, 0.6 and 0.54 m, respectively. Paraquat (Gramoxone^R, 1,1'-dimethyl-4,4'-bipyridinium dichloride) was applied to pool B so a concentration of 20 ppm was obtained. Glyphosate (Roundup^R, isopropylamine salt of N-phosphonomethyl glycine containing 356 g/l glyphosate) was applied to pool C so that a concentration of 200 ppm was achieved. Pool A was used as the control. Viable cell counts of the pool water were

determined at 2-day intervals by using the spread plate method with Nutrient Agar for a total of 30 days after application of the herbicides. All agar plates were incubated at 25°C for 48 hours before the number of bacterial colony forming unit (CFU) was counted. Two bacteria of most frequent occurrence were identified as Aeromonas hydrophila C-1 which was a facultative anaerobic strain, and Pseudomonas chlororaphis L-1 which was a strictly aerobic strain. These two bacteria were used in subsequent experiments. The present results indicate that aquatic bacteria in general are more susceptible to paraquat than the soil microflora and human bacteria in terms of paraquat concentration applied to the aquatic environment. Since in situ study confirms the inhibitory effects of these two herbicides on aquatic bacterial populations and it is conceivable that communities of higher trophic level in the aquatic environment might also be affected. Consequently, consideration must be given to the possibility of contamination of non-target environment such as streams, ponds and lakes when applying paraquat and glyphosate in the field.

4. Fletcher, K. and B. Freedman. 1985. Effects of the herbicides glyphosate, 2,4,5-trichlorophenoxyacetic acid, and 2,4-dichlorophenoxyacetic acid on forest litter decomposition. Canadian Journal of Forest Research 16: 6-9.

Laboratory studies with two leaf litter and one forest floor substrate showed that the herbicides 2,4-dichlorophenoxyacetic acid (2,4-D),2,4,5-trichlorophenoxyacetic acid(2,4,5-T), a 50:50 mixture of these, and glyphosate all had toxic thresholds at which they reduced decomposition. However, in all cases, the thresholds were >50 times higher than residue concentrations that occur in the field after silvicultural herbicide treatments. In a field study at one site, no measurable 1-year postspray effects on litter decomposition were found among treatment plots sprayed at 0.0, 3.4 or 6.7 kg 2,4,5-T/ha.

5. Ghassemi, M., S. Quinlivan, and M. Dellarco. 1982. Environmental effects of new herbicides for vegetation control in forestry. Environment International 7: 389-402.

Environmental fate of and toxicity data for ammonium ethyl carbamoylphosphonate [fosamine ammonium], N-(phosphonomethyl)-glycine [glyphosate], and 3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione[hexazinone] which appear promising for vegetation control in forestry are reviewed. None of the three herbicides is very persistent in soil, with half-lives reported of about 7-10 days for fosamine ammonium, 8-19 weeks for glyphosate, and 1-6 months for hexazinone, depending on soil type and climatic conditions. Degradation in soil is primarily via microbial routes. Whereas hexazinone is a

very mobile herbicide (with mobility dependent on soil type), fosamine ammonium and glyphosate are strongly adsorbed and not readily leached in many soil types. Based on bioassay results, the three herbicides exhibit "very low" to "low" toxicity. Fosamine ammonium is not mutagenic and was not teratogenic when fed to pregnant rats at 10,000 ppm. Data on hexazinone indicate no carcinogenic effect in rats, negative in bacterial and mammalian point mutation assays, and not embryotoxic or teratogenic at up to 5000 ppm in diet of rats. The three herbicides have minimum-to- nil effect on soil microorganisms and exhibit little or no potential for bioaccumulation. Limitations of the available data are discussed and suggestions are made for future studies.

6. Gomez, M.A. and M.A. Sagardoy. 1985. Influence of glyphosate herbicide on the microflora and mesofauna of a sandy soil in a semiarid region. Revista Latinoamericana de Microbiologia 27: 351-358. (Argentina)

Refer to Terrestrial Invertebrates Section (page 27).

7. Gomez, M.A. and M.A. Sagardoy. 1985. The effect of glyphosate on aerobic bacteria that colonize a sandy soil. Anales de Edafologia y Agrobiologia 44: 119-130. (Argentina)

From a sandy soil of the semiarid zone of the province of Buenos Aires, Argentina, 519 bacterial strains were isolated and their genera were identified. Furthermore, the effect of the herbicide on the principal microbial groups was also studied. The results indicate that within the gram positive bacteria, coryneform bacteria and Bacillus spp. were predominant microorganisms. In the gram negative bacteria the Acinetobacter was found to be the dominant genus. The herbicide, at different doses, had little effect on the bacteria that colonize the soil. There was no deleterious effect detected on the potential of these bacterial strains as participants in the nitrogen cycle. The application of the herbicide to sterilized soil at the dose of 40 L/ha did not produce any deleterious effect on eurythermic bacteria of the types coryneform, Bacillus spp. or Acetobacter 307. However, after 10 days of incubation, the number of Acinetobacter 218 was found to decrease. The imperceptible effect produced by glyphosate on the bacteria which normally colonize such soil suggests that the use of the herbicide would not produce any significant alteration in that biological component of the ecosystem soil.

8. **Grossbard, E. 1985. Effects of glyphosate on the microflora: with reference to the decomposition of treated vegetation and interaction with some plant pathogens. In: The Herbicide Glyphosate. Edited by E. Grossbard and D. Atkinson. Butterworths, London. (United Kingdom)**

(*) Although more research is required to clarify the interactions of glyphosate with the microflora a few common threads lead through the labyrinth of observations. In pure culture, many microbial species are inhibited by glyphosate. This effect is selective, variable in magnitude and frequently dose related. In terms of agricultural practice, inhibitory effects, especially of the celluloytic fungi, occur at concentrations well above those normally used in agriculture. Moreover, the amount of herbicide which reaches the soil is smaller than that applied, because a certain proportion of glyphosate, which is foliar applied, is retained by the vegetation. Also glyphosate is adsorbed and degraded in soil; one reason why the microorganisms examined tolerate generally the glyphosate in soil much better than in pure culture in laboratory media. Furthermore, the numbers of propagules of all microbial groups in soil increased following glyphosate treatment. Despite the shortcomings of techniques for enumerating microbial propagules in soil, this observation implies utilization by soil microflora of either glyphosate itself or its degradation products. A reassuring aspect of the behaviour of glyphosate is that it does not curtail nitrification in the soil, an activity affected adversely by some other herbicides. Mineralization of nitrogen, even at high concentrations of glyphosate, is enhanced, as is another important function-cellulose decomposition. On present evidence, however, it may be concluded that soil fertility per se is unlikely to be impaired by the agricultural use of glyphosate.

9. **Grossbard, E. and S.L. Cooper. 1974. The decay of cereal straw after spraying with paraquat and glyphosate. Proceedings of the British Weed Control Conference 12: 337-343. (United Kingdom)**

The effect of paraquat (1.7 kg/ha) and glyphosate (3.4 kg/ha) on the decay of C^{14}-labeled rye leaves incubating on the soil surface and of unlabeled barley straw, covered by a shallow layer of soil, was studied in the lab. Paraquat and glyphosate had no effect on the decay of rye leaves on the surface and glyphosate did not affect degradation of barley straw. However, paraquat significantly suppressed the decay of buried barley straw as measured by weight loss, which was, after 16 weeks, between 40 and 55% of the initial weight for control and only between 18 and 26% with paraquat. The addition of NH_4NO_3 increased the extent of decay of barley straw treated with paraquat by about 17% but at the end of the experiment the weight loss was still smaller than for control straw.

10. Grossbard, E. and H.A. Davies. 1976. Specific microbial responses to herbicides. Weed Research 16: 163-169. (United Kingdom)

Herbicides can exert adverse effects on the soil microflora, depending on concentration, though often at higher rates than the herbicidal dose. Examples refer to changes in microbial growth (asulam, linuron, paraquat) and equilibrium (metoxuron), respiration and nitrification in samples from field experiments (linuron, simazine) and laboratory experiments (bentazone, glyphosate, barban, etc), enzyme activities (urease, phosphatase, barban, chlorpropham, linuron) and the decay of sprayed vegetation (glyphosate, paraquat).

11. Grossbard, E. and D. Harris. 1981. Effects on straw decay of the herbicides paraquat and glyphosate in combination with nitrogen amendments. Annals of Applied Biology 98: 277-288. (United Kingdom)

The effects of paraquat were studied at 4-7 kg a.i./ha and of glyphosate at 9.4 kg a.i./ha on the weight loss and rate of O_2 uptake by stems of barley straw, incubated on the soil surface for various periods of time, and stems and leaves of wheat straw on the soil surface or covered with a shallow layer of soil. In general, paraquat reduced weight loss and frequently O_2 uptake. Glyphosate normally had no effect but occasionally it was stimulatory. However, in isolated instances, paraquat was inactive and glyphosate slightly inhibitory. Leaves decayed faster than stems. Burial as well as the addition to straw of leaf protein, nitrochalk, urea and clover plants increased decomposition in all treatments, but nitrogen amendments were less effective in those with paraquat. For example, urea enhanced weight loss after 21 weeks from 19 to 34% of the initial weight in unsprayed wheat straw, from 12 to 24% in paraquat-treated and from 20 to 37% in glyphosate-treated straw, indicating that conditions stimulating decomposition may attenuate but not entirely eliminate the inhibitory effects of paraquat. A repeated addition of nitrogen to straw in various stages of decay increased O_2 uptake in all treatments but least in the paraquat-treated straw, implying that a complete recovery from the initial curtailment of microbial activity, brought about by this herbicide, did not occur. Although the concentration of paraquat used was 9 times greater than the minimum recommended for field application, the degree of inhibition observed in these laboratory experiments was probably not sufficiently great to be of marked economic importance.

12. **Grossbard, E. and G. Wingfield. 1978. Effects of paraquat, aminotriazole and glyphosate on cellulose decomposition. Weed Research 18: 347-353. (United Kingdom)**

Effects of paraquat, activated aminotriazol and glyphosate on cellulose decomposition were studied in laboratory experiments. Herbicides were either incorporated in soil or sprayed onto cellulosic substrates which were incubated either on the surface of soil or buried. Paraquat applied directly to the substrates inhibited their decay, but not when applied to the soil. Aminotriazole incorporated in soil at 500 ppm strongly suppressed decomposition of buried calico, but effects varied with surface incubation. The only effects observed at 150 ppm were occasional stimulation of the decay of surface-incubated calico. Glyphosate applied either to soil or substrate usually stimulated cellulose decay. Numbers of ropagules of cellulolytic fungi were decreased by aminotriazole and glyphosate applied to the soil and by glyphosate and paraquat applied to cellulose, but increased in soil treated with paraquat. In pure culture paraquat was the most, and aminotriazole the least, toxic to the 5 test fungi. Numbers of cellulolytic bacteria were decreased in soil treated with paraquat but the other 2 herbicides either did not affect or stimulated this group.

13. **Harris, D. and E. Grossbard. 1979. Effects of the herbicides Gramoxone W and Roundup on Septoria nodorum. Transactions of the British Mycological Society 73: 27-33. (United Kingdom)**

The action of Gramoxone W (a.i. paraquat) and Roundup (a.i. glyphosate) on vegetative growth, spore formation, germination and pathogenicity of spores of Septoria nodorum Berk. to detached wheat leaf segments, was examined. Both herbicides had inhibitory effects, but Roundup was the more active. At 80 ppm it reduced the growth rates of four isolates by 50-55%, whilst Gramoxone W at 80 ppm produced a 25-40% reduction. Roundup at 80 ppm reduced spore formation by 90% but Gramoxone W was ineffective. Pre-treatment with Roundup reduced spore germination by 60% even when the herbicide was absent from the germination medium. However, with Gramoxone W this inhibition occurred only when the herbicide was incorporated in the germination medium. A potential carry-over of the active ingredient of Gramoxone W was indicated by the presence of C^{14} in washed spore suspensions prepared from cultures grown on media containing C^{14}-labelled paraquat, and by the greater severity of lesions on detached leaves infected by spores from cultures grown with Gramoxone W, when compared to lesions produced by untreated spores. Roundup pre-treated spores produced lesions less severe than control, except at high inoculum density, where in some experiments lesion severity was enhanced late in the incubation period.

14. Heinonen-Tanski, H., L. Montonen, L.R. Ervio, S. Jonnila and B. Pessala. 1985. The effects of chlorsulfuron, glyphosate, metribuzin and TCA on soil nitrification capacity and dehydrogenase activity. In: Comportement et Effects Secondaires des Pesticides dans le Sol, Versailles, France. June 4-8, 1984. Pp. 183-189. (Finland)

In field trials at Jokioinen and Ruukki, Finland, potatoes were treated with glyphosate, metribuzin or TCA and barley with chlorsulfuron all applied at the normal rate or 3 times this rate. The effects of the herbicides on soil dehydrogenase and nitrification activity were studied. Chlorsulfuron and glyphosate had little effect on soil dehydrogenase and nitrification, but metribuzin and TCA reduced both activities especially in clay soils. The effects of TCA were still evident 1 year after application.

15. Heinonen-Tanski, H., C. Rosenberg, H. Siltanen, S. Kilpi and P. Simojoki. 1985. The effect of the annual use of pesticides on soil microorganisms, pesticide residues in the soil and barley yields. Pesticide Science 16: 341-348. (Finland)

A study has been made of the influence of pesticides used annually on soil microorganisms and crop yields (Finland). The persistence of these pesticides in the soil was also investigated. The herbicides MCPA, glyphosate, maleic hydrazide and tri-allate, and the insecticide parathion, were applied on experimental plots on which barley was grown during the years 1973-1981. The fungicide 2-methoxyethylmercury chloride was used every year for dressing the seeds grown in pesticide-treated plots. The pesticide treatments did not affect significantly the numbers of several groups of soil microorganisms. A slight increase was, however, observed in the nitrification activity in the soil. The barley yields were on average higher on pesticide-treated plots than on controls because of successful weed control. Pesticide residues in the soil were generally very low; for example, for parathion they were below 0.02 mg/kg within 11 days, and for MCPA 0.06 mg/kg within 7 days. However, the glyphosate residue was 1.6 mg/kg in the autumn 2 days after the treatment, and the residue settled to a level of 0.2 mg/kg during the following summer. No clear dependence was observed between the residue level and the time between treatment and sampling.

16. Heinonen-Tanski, H., H. Siltanen, S. Kilpi, P. Simojoki, C. Rosenberg and S. Makenen. 1986. The effect of the annual use of some pesticides on soil microorganisms, pesticide residues in soil and carrot (Daucus carota) yields. Pesticide Science 17: 135-142. (Finland)

The study deals with the effect of common, annually-used pesticides on soil microorganisms, pesticide residues in soil,

and carrot (Daucus carota) yields in central Finland. Linuron residues in carrot roots were also analyzed. Thiram + lindane and dimethoate were applied from 1973-1981 at the commercially recommended doses on experimental plots of carrots, linuron was applied at twice the recommended rate from 1973-1979 and at the normal rate thereafter and in addition TCA was applied in 1978. Maleic hydrazide was used in the years 1973-1976, and glyphosate after 1977. The numbers of different soil microorganisms, their activities and the pesticide residues were studied from autumn 1978 to 1981. The pesticide treatments reduced the growth of soil algae but increased the total number of microorganisms and the number of aerobic spore-forming bacteria. Linuron residues in the soil were 0.9-2.8 mg/kg in the growing season and 1.2-1.9 mg/kg in the autumn, 3 months after application. The residues of glyphosate in the soil were 0.7 mg/kg in the autumn, 41 days after the treatment, and had declined to a level of about 0.2 mg/kg by the following summer. In the pesticide-treated plots the carrot yield was only 20-60% of the yield in the hand-weeded plots. The herbicide program controlled most of the annual weeds but not couchgrass Elymus repens and milk sow-thistle Sonchus arvensis.

17. **Hendrix, P.F. and R.W. Parmelee. 1985. Decomposition nutrient loss and microarthropod densities in herbicide-treated grass litter in a Georgia piedmont USA agroecosystem. Soil Biology and Biochemistry 17: 421-428.**

A litterbag experiment was made to investigate the influence of the herbicides atrazine, paraquat and glyphosate on several aspects of the decomposition of grass litter in a fallow field. Litterbags containing dried Johnson grass (Sorghum halepense) leaves were dipped in herbicide solutions at recommended and 10 times recommended field application rates, placed in the field, and randomly collected every 3 weeks from July-November, 1982. At the highest treatment levels of paraquat and glyphosate, the leaves showed slower weight loss, faster losses of P, Ca and Mg, and higher densities of microfloral-grazing microarthropods than untreated controls. Using a conceptual model of the decomposition subsystem, it is hypothesized that herbicide treatment altered the system by promoting microbial utilization of the herbicide or additive as a carbon source; increasing the importance of microarthropod grazing relative to comminution; eliminating or reducing the importance of the predatory microarthropods; and increasing the rate of nutrient loss from the litter via microbial and microarthropod activity. The system thus became simplified with fewer recycling loops, accelerated soluble nutrient loss, and slower decay of carbon from the leaf tissue.

18. **Levesque, C.A., J.E. Rahe and D.M. Eaves. 1987. Effects of glyphosate on Fusarium spp.: its influence on root colonization of weeds, propagule density in the soil, and crop emergence. Canadian Journal of Microbiology 33: 354-360.**

Glyphosate is a broad spectrum herbicide that can lead to root rot like damage on crops. This study was undertaken to investigate the effect of glyphosate on the root-colonizing Fusarium spp. The research was conducted at two sites. Site one was densely covered with perennial weeds, and site two with annuals. At site one, spraying the weed cover with glyphosate increased ($p < 0.05$) the level of colonization by Fusarium spp. in Ranunculus repens and Holcus lanatus, but not in Stellaria media and Plantago lanceolata. At site two, glyphosaste enhanced colonization in Spergula arvensis, Stellaria media, Echinochloa crusgalli, and Chenopodium album, but not in Capsella bursa-pastoris and Polygonum persicaria. At both sites, the number of colony-forming units of Fusarium spp. per gram of dried soil was increased by the application of glyphosate. Nevertheless, crops subsequently sown in the field containing the annual weeds were not detrimentally affected by glyphosate treatment of these weeds.

19. **Mallik, M.A.B. and K. Tesfai. 1985. Pesticidal effect on soybean and Rhizobia symbiosis. Plant and Soil 85: 33-42.**

Relative compatibility of selected pesticides at 2 levels of application: recommended rate and 5 times or 10 times with soybean-rhizobia symbiosis was tested in pot culture experiments using a prepared peat inoculant. PCNB (pentachloronitro benzene), carboxin and carboxin + captan at recommended level were innocuous to growth, nodulation, N_2-fixation and total nitrogen content of shoot. Carboxin and carboxin + captan but not PCNB at 10 times recommended level proved detrimental to nodulation and N_2-fixation. Carbaryl and malthion at recommended level had no adverse effect but at 10 times recommended level severely reduced N_2-fixation but not other parameters. Acephate, diazinon and toxaphene at both levels reduced N_2-fixation and total nitrogen content but not growth and nodulation. All five herbicides used at recommended and 5 times recommended level adversely affected nodulation and N_2-fixation. Glyphosate proved least toxic to all parameters. 2,4-D at recommended level was less harmful to nodulation and N_2-fixation than trifluralin, alachlor and metribuzin.

20. **Marsh, J.A.P., H.A. Davies and E. Grossbard. 1977. The effect of herbicides on respiration and transformation of nitrogen in 2 soils. Part 1 metribuzin and glyphosate. Weed Research 17: 77-82. (United Kingdom)**

The effects of metribuzin and glyphosate at 100 ppm on microbial CO_2 evolution and nitrogen transformation in 2 soils were investigated in the laboratory. Both herbicides reduced CO_2 evolution from Boddington Barn soil (organic carbon content 1.5%, pH 6.6) at some dates, but neither gave any consistent effects on Triangle soil (organic carbon content 4.0%, pH 5.1). Both metribuzin and glyphosate stimulated mineralization of nitrogen for at least 9 weeks. Only metribuzin on Triangle soil gave any indication of inhibition of nitrification. Metribuzin degraded more rapidly in Triangle soil than in Boddington Barn.

21. **Mueller, M.M., C. Rosenberg, H. Siltanen and T. Wartiovaara. 1981. Fate of glyphosate and its influence on nitrogen cycling in two Finnish agriculture soils. Bulletin of Environmental Contamination and Toxicology 27: 724-730. (Finland)**

(*) During an energy forest experiment in Suomusjarvi, Kettula (located in Southern Finland) glyphosate was used to destroy indigenous flora, mainly quackgrass, before replanting. Since the degradation rate of glyphosate and its biological impact are known to vary and field data were largely unavailable, it was decided that both the persistence of glyphosate and its effects on the nitrogen cycling processes fundamental to the energy forest experiment should be investigated. Both fields, SK-1 (loam soil) and SK-2 (fine silt soil), were treated on the 14th of September, 1978 with glyphosate 2.6 kg/ha. Two sites of ca. 100 m^2 were chosen at each field and sampled immediately after the application of glyphosate, 1 month and eight months later. Control samples were collected before glyphosate was applied. It is concluded that glyphosate degraded even at low temperature conditions, and it is not to be expected, that the application of glyphosate will affect directly nitrogen fixation, nitrification or denitrification activity in these soils.

22. **Pipke, R., A. Schulz and N. Amrhein. 1987. Uptake of glyphosate by an Arthrobacter sp. Applied Environmental Microbiology 53: 974-978. (Federal Republic of Germany)**

The uptake of glyphosate (N-[phosphonomethyl]glycine) by an Arthrobacter sp. which can utilize this herbicide as its sole source of phosphorus was investigated. Orthophosphate suppressed the expression of the uptake system for glyphosate and also compared with glyphosate for uptake. The K_m for glyphosate uptake was 125 uM, and the K_i for orthophosphate was 24 uM.

Organophosphonates as well as organophosphates inhibited glyphosate uptake, but only organophosphates and orthophosphate suppressed the uptake system. Glyphosate uptake was energy dependent, had a pH optimum of 6 to 7, and was differentially affected by divalent cations.

23. Powell, C.L. and D.J. Bagyaraj. 1985. Effects of some herbicides and fungicides on the in-vitro growth of the endomycorrhizal fungus Pezizella ericae. New Zealand Journal of Agricultural Research 27: 581-586. (New Zealand)

The endomycorrhizal fungus, P. ericae (Read), was grown in modified Norkran's broth amended with several rates of 2 herbicides (hexazinone and glyphosate) and 3 fungicides (etridiazole, vinclozolin and benomyl). At equivalent rates to those used in the field, there was no significant effect of hexazinone, glyphosate or etridiazole on fungal dry matter (DM) yields after 30 days incubation at 20 degrees Celcius. However, vinclozolin and benomyl reduced fungal DM production by 48% and 82%, respectively, although it is likely that P. ericae would be able to tolerate the low rates at which these fungicides would be present in plant roots under field conditions.

24. Preston, C.M. and J.A. Trofymow. 1987. Effects of glyphosate on biological activity of two forest soils. Proceedings of the Carnation Creek Herbicide Workshop, Nanaimo, B.C. December 8-10, (In press).

The results from laboratory and field trials are presented. To examine possible effects of glyphosate on carbon dioxide evolution and nitrogen transformations, forest floor and mineral soil from a Douglas-fir site at Shawnigan Lake (Vancouver Island) were incubated with glyphosate (10 and 50 ug/g) with or without N^{15}-labelled urea (200 ug/g N). No significant effects of glyphosate were found on carbon dioxide evolution, urea hydrolysis, immobilization or ammonium or nutrification, for either soil depth or level of glyphosate application. In field studies, soil fauna and microflora populations were monitored in surface organic layers prior to and following glyphosate application on alder covered sites at Carnation Creek (Vancouver Island). In a six month study, glyphosate had no significant long-term effects on either soil fauna or microflora populations. Soil microflora populations in herbicide treated plots fluctuated and then returned to control levels during an intensive one month field sampling trial.

25. **Roslycky, E.B. 1982. Glyphosate and the response of the soil microbiota. Soil Biology and Biochemistry 14: 87-92.**

Limited information on the effect of glyphosate (N-phosphonomethylglycine) on soil microorganisms justified an inquiry into the response of soil actinomycetes, bacteria and fungi in terms of their respiration, and sensitivity of isolates. Low concentrations of glyphosate had little effect on total populations of these organisms during the 214-day experiment, while high concentrations initially increased actinomycete and bacterial numbers by 2 and 1 1/2 logs, respectively. The stimulation was followed by a decline and fluctuation showing a gradual increase in numbers. The respiration rates of the soil microbiota in soil suspensions, showed some irregular stimulation and retardation with up to 10 mu.g glyphosate/ml. In contrast high doses suppressed O_2 uptake by the microbiota. Fungi were the least affected. Pronounced inhibition of actinomycete and bacterial respiration was in agreement with the results from isolate replication. The results indicated both stimulation and inhibition of O_2 uptake by some organisms within these groups. In contrast to some reports of limited, short-term inquiries these results showed considerable effects of glyphosate on soil microorganisms.

26. **Torstensson, N.T.L. and A. Aamisepp. 1977. Detoxification of glyphosate in soil. Weed Research 17: 209-212. (Sweden)**

Detoxification of glyphosate [N-(phosphonomethyl)-glycine] in nonsterile and autoclaved soils was followed by bioassay with wheat. Comparisons were made with detoxification of MCPA [2-methyl-4-chlorophenoxyacetic acid] under similar conditions followed by bioassay with spring rape. The well known pattern for microbial metabolism of MCPA with a lag phase preceeding the rapid degradation was shown. The initial rapid inactivation of glyphosate is by adsorption, but the results also clearly indicate that the further disappearance of activity depends mainly on microbial degradation. Glyphosate does not seem to sustain microbial growth, which indicates that it is degraded by co-metabolism. In autoclaved soil the possibility of a slight chemical degradation or an adsorption that becomes stronger with time could not be excluded.

27. **Vasilev, K. 1982. Glyphosate effect on test microorganisms under laboratory conditions. Khigiena I Zuraveopazvane 25: 346-351. (Bulgaria)**

The effect of the herbicide glyphosate was studied on some representative species of water saprophilic microflora and of some sanitary-indicative and pathogenic intestinal microorganisms. Strains from the following species were used:

Pseudomonas aeruginosa, Escherichia coli and Salmonella typhimurium. The experiments were carried out under laboratory conditions with and without aeration, with 3 concentrations of glyphosate (10, 100 and 300 mg/dm^3). The quantitative changes in the microorganisms were studied by inoculations on solid nutritive media. Glyphosate effect on test microorganisms was concentration-dependent. At a concentration of 10 mg/dm^3, glyphosate induced an increase in the quantity of the test microorganisms, at a concentration of 300 mg/dm^3, an inhibitory effect was established, manifested by a reduction of the number of microorganisms. All tested glyphosate concentrations, in combination with aeration, induced a sharp decrease in the quantity of the test microorganisms.

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